

I²t testing for current-limiting fuses

General

Eaton utilizes an I²t test in its Cooper Power™ series products to verify and guarantee that every current-limiting fuse produced will meet their published minimum melt I²t levels and will not operate prematurely.

Purpose of test

Since a current-limiting fuse is a "blind" assembly, it is impossible to visually inspect its internal construction after it is assembled. Therefore, small flaws that can occur during the production process could significantly affect the operating characteristic of the fuse.

The proprietary I²t test will detect all such flaws. The purpose of the test is to verify the minimum I²t characteristics, to assure element integrity during transformer inrush conditions and to verify proper element size. Without such a production test, a fuse could go into service that might operate at lower than intended time-current conditions. As a result, customers would experience unnecessary outages and possible fuse failure. To address this concern, Eaton's performs a 100% production I²t test program beyond that practiced by most fuse manufacturers.

Resistance check is not enough

Many manufacturers of current-limiting fuses limit their production testing to a resistance check. While this remains a valuable quality assurance tool, it does not give sufficient evidence that the fuse will withstand the various short time currents it will encounter in service. Such currents include transformer inrush, cold load pickup, and switching surges. It also does not give assurance that the element remained undamaged during the production process.

Resistance measurements can be quite sensitive, but the realities of production impose a broad tolerance on fuse elements. Usually a manufacturer will allow a +/- 10% tolerance on the resistance of a current-limiting fuse element. This tolerance can mask the variations that occur as a result of a slight flaw or damaged element.

The silver ribbon elements of most current-limiting fuses are perforated with circular holes. The purpose of the holes is to control the arc voltage across the fuse during operation. Each length of ribbon containing a hole could be viewed as a section of relatively high resistance, and the length between holes could be considered relatively low resistance. Thus, we could view the element as a number of parallel resistances in a series.

Let us suppose that an element is damaged severely enough to cause a change in melt characteristics, but not so severely that the damage is obvious to the fuse assembler. Such damage might consist of a nick in the edge of the element. Experiments have shown that a nick extending half way from the element edge to one of the holes will result in a 44% reduction in minimum melt I²t for that element.

That same nick will have much less effect on resistance. To illustrate this, assume an element 22" long with 44 holes spaced 1/2" apart. The change in resistance can be shown by considering each length of ribbon containing a hole as one (1) resistance unit (R). Or in the example, 44R since there are 44 segments with holes. A nick half way through one side to a hole will increase the resistance of the section from 1R to 1.33R. Thus the total resistance is changed from 44R to 44.33R, a per unit change of .75%, well within the accepted +/- 10% production tolerance. In actuality, the change in resistance would be even less because the silver between each hole adds resistance to the total element. This clearly shows that an additional test is needed.



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Performance of test

An acceptance test is one which verifies the minimum melt I²t of the fuse. In this way a small nick in the element ribbon which makes a negligible difference in resistance, but a significant difference in I²t, will be detected. This is accomplished by pulsing each current-limiting fuse produced with a short pulse of energy.

The pulse of energy is calibrated to contain 95% of the published minimum melt I²t, of the fuse to be tested. The wave-form of the pulse is checked by a digital transient recorder and its energy content is calculated by computer. Experiments have shown that a good, undamaged fuse will withstand an indefinite number of such pulses with no detrimental effects.

In production testing, fuses are subjected to two pulses - a method particularly important with multiple element fuses. This is because the first pulse might not completely open a defective fuse, but it will dramatically lower its I²t melt capability. The second pulse will completely open all elements.

After being pulsed, each fuse has its resistance and integrity checked by means of a millivolt drop test. A known current is placed through the fuse. Since its resistance is known, it will produce a millivolt drop across the fuse. This voltage drop is measured and compared to the standard. Any fuse that proves discontinuous or otherwise out of tolerance is rejected.

The millivolt drop test accomplishes two things. It determines whether the test subject has blown as a result of the I²t Test, and it determines whether the fuse resistance is within tolerance, thus assuring the correct element size. Therefore, fuses that test within tolerance are proven to be continuous, of the proper current rating, and capable of withstanding I²t levels at least as large as the published minimum melt rating for that size fuse.

Conclusions

A small nick in the element of a current-limiting fuse can cause a significant lowering of minimum melt I²t characteristics. Such changes can be enough to cause fuses to operate prematurely resulting in unnecessary outages.

Production tolerances can mask small changes in resistance, so that resistance checks alone are not adequate to assure fuse quality.

Problems due to these conditions can be eliminated by a test that verifies the minimum melt I²t of each fuse produced. Eaton's I²t test provides the additional test that assures each current-limiting fuse produced will withstand inrush, cold load pick-up, and other short term high energy currents common on electrical distribution lines.

It is recommended that users of other manufacturer's current-limiting fuses require that they be tested similarly to assure maximum fuse reliability.

It should also be recognized that fuse elements can be damaged in the field (due to miscoordination, high current surges, or clearing multiple phase faults). In these cases an I²t Inrush Withstand Test, as described, is advisable if suspect fuses are to be returned to service.

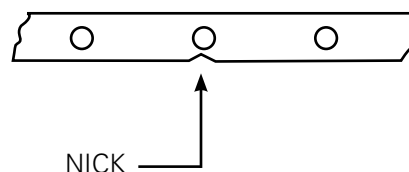


Figure 1. Damaged current-limiting fuse ribbon element.

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